MICROCOPY RESOLUTION TEST CHART

AD-A193 071

②

IEMIS FLOODPLAIN MAPPING BASED ON A LIDAR DERIVED DATA SET

Jack K. Stoll

U.S. Army Engineer Waterways Experiment Station
Vicksburg, Mississippi

Dale A. Lehman, P.E.

Greenhorne & O'Mara, Inc.
Greenbelt, Maryland

Daniel M. Cotter

Federal Emergency Management Agency
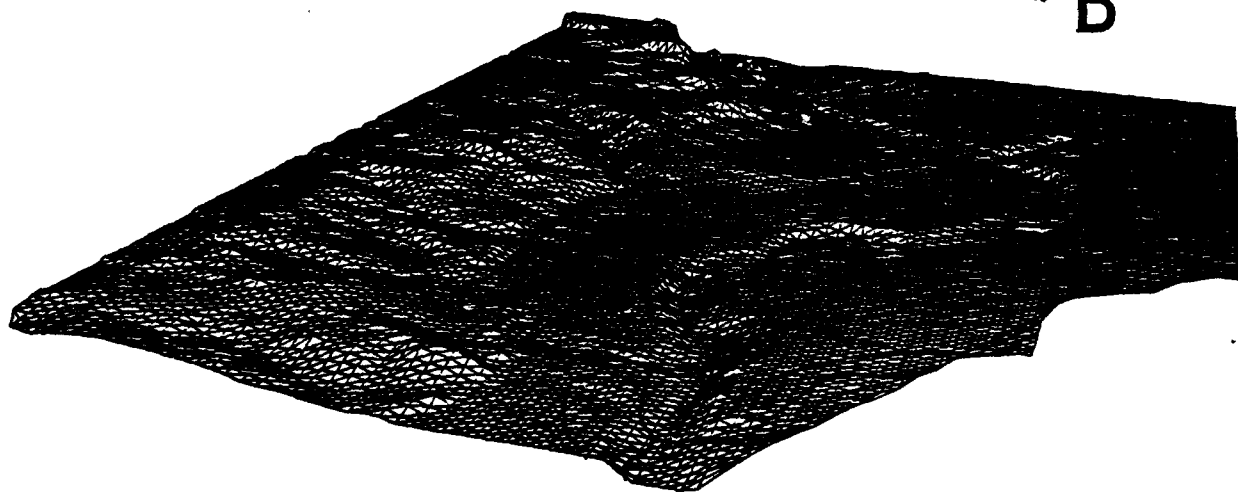Washington, D.C.

DTIC
ELECTE
S MAR 3 1 1988
D
D

88 3 29 093

ADA193071

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION Unclassified/Unlimited	1b RESTRICTIVE MARKINGS
2a SECURITY CLASSIFICATION AUTHORITY	3 DISTRIBUTION/AVAILABILITY OF REPORT
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S)	5. MONITORING ORGANIZATION REPORT NUMBER(S)

6a. NAME OF PERFORMING ORGANIZATION U.S. Army Engineer Waterways Experiment Station	6b OFFICE SYMBOL (If applicable) CoE/WES	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) Vicksburg, Mississippi		7b. ADDRESS (City, State, and ZIP Code)

8a. NAME OF FUNDING/SPONSORING ORGANIZATION	8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER

8c. ADDRESS (City, State, and ZIP Code)	10 SOURCE OF FUNDING NUMBERS			
	PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification) IEMIS Floodplain Mapping Based on a Lidar Derived Data Set

12. PERSONAL AUTHOR(S) Stoll, Jack K.; Lehman, Dale A. (Greenhorne & O'Mara); Cotter, Daniel M. (FEMA)

13a. TYPE OF REPORT FINAL	13b. TIME COVERED FROM ___ TO ___	14. DATE OF REPORT (Year, Month, Day) 880205	15. PAGE COUNT 20

16. SUPPLEMENTARY NOTATION Presented at the Fourth International Conference on Interactive Information and processing systems for meteorology, Oceanography and Hydrology of the AMS

17.	COSATI CODES		18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Topographic Data, Floodplain, Hazards, Mapping, Light Detection and Ranging (LIDAR)

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The collection of accurate topographic data is the single most costly task in the analysis of flood hazards. Traditional field survey techniques are expensive to employ, and the time required to gather topographic data through field or aerial surveys is an obstacle to the timely completion of the analysis. Laser ranging technology offers an alternative to conventional field and potogrammetric surveying techniques. Laser ranging devices mounted on aircraft, normally referred to as LIDAR (Light Detection and Ranging) systems, can collect topographic data at extremely high rates of speed. These data are collected in a digital form. This collection system provides the mechanism for immediate processing and formatting of terrain data for direct input to hydraulic models.

To determine whether LIDAR systems can be used to collect topographic data for FISs. the U.S. Army Corps of Engineers' (COE) Waterways Experiment Station (WES) and FEMA conducted a joint test of the technology as part of the FIS for Hays County, Texas. The

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified/Unlimited
22a NAME OF RESPONSIBLE INDIVIDUAL Daniel Cotter	22b TELEPHONE (Include Area Code) 202/646-2757	22c. OFFICE SYMBOL FEMA

19. ABSTRACT continued

purpose of this paper is to describe the test, demonstrate the use of digital topographic data for floodplain mapping, and illustrate the application of the automated mapping capabilities of the Integrated Emergency Management Information System (IEMIS) to FISs.

IEMIS FLOODPLAIN MAPPING BASED ON A LIDAR-DERIVED DATA SET

Jack K. Stoll

U.S. Army Corps of Engineers Waterways Experiment Station
Vicksburg, Mississippi

Dale A. Lehman, P.E.

Greenhorne & O'Mara, Inc.
Greenbelt, Maryland

Daniel M. Cotter

Federal Emergency Management Agency
Washington, D.C.

I. INTRODUCTION

The collection of accurate topographic data is the single most costly task in the analysis of flood hazards. Hydraulic models, which are used to calculate the elevations attained by a given flood discharge passing through a river channel, are based on topographic data. In conducting Flood Insurance Studies (FISs), the results of which are used in the administration of the National Flood Insurance Program (NFIP), the Federal Emergency Management Agency (FEMA) typically expends 35 percent of an FIS budget on topographic surveys.

Traditional field survey techniques are expensive to employ, and the time required to gather topographic data through field or aerial surveys is an obstacle to the timely completion of FISs. Other factors contributing to problems associated with completing field surveys include the remoteness of study areas, the distances and terrain over which equipment must be hand-carried during surveys, and the need to obtain permission from owners of private land to perform surveys on their property.

When aerial survey methods are employed, cloud cover, sun angle, and foliage density can limit the flying times for photogrammetry. Even after photography has been obtained, considerable time is required to compile topographic data from the imagery. Laser ranging technology offers an alternative to conventional field and photogrammetric surveying techniques. Laser ranging devices mounted on aircraft, normally referred to as LIDAR (Light Detection and Ranging) systems, can collect topographic data at extremely high rates of speed. These data are collected in a digital form. This collection system provides the mechanism for immediate processing and formatting of terrain data for direct input to hydraulic models.

To determine whether LIDAR systems can be used to collect topographic data for FISs, the U.S. Army Corps of Engineers' (COE) Waterways Experiment Station (WES) and FEMA conducted a joint test of the technology as part of the FIS for Hays County, Texas. The purpose of this paper is to describe the test, demonstrate the use of digital topographic data for floodplain mapping, and illustrate the application of the automated mapping capabilities of the Integrated Emergency Management Information System (IEMIS) to FISs.

II. BACKGROUND

The concept of mounting laser ranging devices on aircraft for the purpose of collecting topographic data for FISs has been around since at least 1970 (Brown 1987). The U.S. Geological Survey (USGS) instituted a major program in 1974 to develop the automated profiling of terrain system (APTS). Specifications for the APTS airborne LIDAR and auxiliary instrumentation were adequate to obtain topographic data meeting the accuracy requirements established for FISs.

The most difficult task in the collection of topographic data with an airborne LIDAR system is the accurate determination, in real time, of the three-coordinate position of the aircraft. In developing a prototype system for airborne LIDAR topographic data collection, the USGS incorporated into the APTS an inertial guidance system and a capability for repetitive updates of the inertial guidance system with independent positional information. The vertical distance between the aircraft and the ground is measured by the laser ranging device. When the positional information on aircraft altitude and geographic coordinates are combined with the laser ranging data, the elevation of the ground surface can be determined for a specific location.

The prototype system developed by the USGS was mounted in a twin engine DeHavilland Twin Otter aircraft. Using that system, the USGS concluded that ground elevations along the aircraft flight path can be determined to a 15-centimeter vertical and a 61-centimeter horizontal accuracy at the 90-percent reliability level (Brown 1987, 91). Operating costs for the APTS are estimated by Brown (1987, 81) at $5,000 per flight hour.

The Federal Insurance Administration (FIA), responsible within FEMA for the administration of the NFIP, commissioned a study by the Jet Propulsion Laboratory (JPL), completed in 1976 (JPL 1976), to evaluate the feasibility of using LIDAR to collect FIS topographic data. The JPL study indicated that development of an airborne LIDAR system, similar in concept and design to the APTS configuration, was technically feasible. However, FIA elected not to pursue development of the system at that time.

The USGS and FEMA are not the only organizations that have evinced an interest in LIDAR systems, and investigations of LIDAR system applications have not been limited to evaluations of those systems as a means of gathering topographic data for FISs. The National Aeronautics and Space Administration (NASA) and the COE have both been conducting research and development activities using aircraft-mounted LIDAR since the mid-seventies, (Krabill 1984, 686). Those activities involved the use of LIDAR systems for bathymetric surveying (Hoge 1980) and topographic mapping.

2

A-1

Topographic mapping experiments performed jointly by NASA and the COE using fixed-wing aircraft showed that the root-mean-square difference between LIDAR data and photogrammetric data is less than 50 centimeters (Krabill 1984, 689). In addition to demonstrating the accuracy of LIDAR systems, these experiments revealed that the density of topographic information provided by LIDAR is much greater than the density of data obtained with ground survey or photogrammetric methods. The experiments also demonstrated the ability of LIDAR systems to provide ground elevation data in areas of dense foliage.

The results of these research and development activities, combined with the availability of a handful of private companies offering commercial LIDAR topographic surveying services, led the FIA to join WES in a demonstration project to test the use of an airborne LIDAR system for the preparation of an FIS meeting the conditions and requirements specified by FIA.

III. OBJECTIVES OF LIDAR DEMONSTRATION PROJECT

The overall objective of the LIDAR demonstration project was to determine whether topographic data collected from an airborne LIDAR system would meet the accuracy requirements established for FISs. Field-survey and photogrammetric data were to be compared with LIDAR data, and the effects of vegetative cover, land use, and topographic relief on LIDAR data collection were to be evaluated to define floodplain conditions where future applications of LIDAR technology would be feasible. Other objectives of this project were to determine whether the differences between computed water-surface elevations determined with LIDAR data and those determined with field-survey data are minor and to prepare a digital floodplain map that could be stored on IEMIS (FEMA 1987).

Information about the time and costs associated with the LIDAR data collection effort was recorded. These data are being compared with the time and cost data for ground and photogrammetric surveys. Through that comparison, FIA and the COE hope to identify the circumstances under which the costs of performing LIDAR surveys are outweighed by the benefits offered by rapid, digital data collection. The time and cost comparisons are not yet complete.

The FISs conducted by FIA, and most of the studies performed by the COE, are not of a research and development nature. The hydraulic and hydrologic studies performed by these agencies usually must be completed under the constraints of established budgets and schedules. Topographic data collection systems employed for these studies must therefore operate consistently and reliably. For the demonstration project, LIDAR data were collected during an ongoing FIS to simulate the use of the system in a production mode.

IV. CONDUCT OF STUDY

For the objectives of the LIDAR demonstration project to be achieved, a study site was required that was the subject of an ongoing FIS; exhibited a suitable range of variation in vegetation cover, land use and topographic features; and for which horizontal and vertical ground control could be established without undue difficulty. As a result of a meeting between COE and FIA representatives in June 1984, the Rio Blanco River, Hays County, Texas, was selected as the study site. Hays County was the subject of an FIS being performed by the Ft. Worth District of the COE for FIA. Land cover in the Rio Blanco basin includes dense tree canopy, thick grasses, bare ground, cultivated fields, crops, and cultural features such as railroads, gravel roads, bituminous and concrete paved roads, quarries, and buildings. Topographic features of the area include nearly vertical, tall bluffs; exposed bedrock and sand bars in the river channel bottom; wide, flat floodplain terraces; and dissected uplands.

WES managed the technical and administrative aspects of the LIDAR data collection. As part of its work, WES conducted an extensive field reconnaissance of the area before collecting data. Of particular importance was the selection of terrain profiles to be collected by the LIDAR system and the establishment of a network of ground control points. The terrain profiles, or cross sections, and ground control point locations are depicted by Figure 1. A total of 29 cross sections was identified for LIDAR data collection.
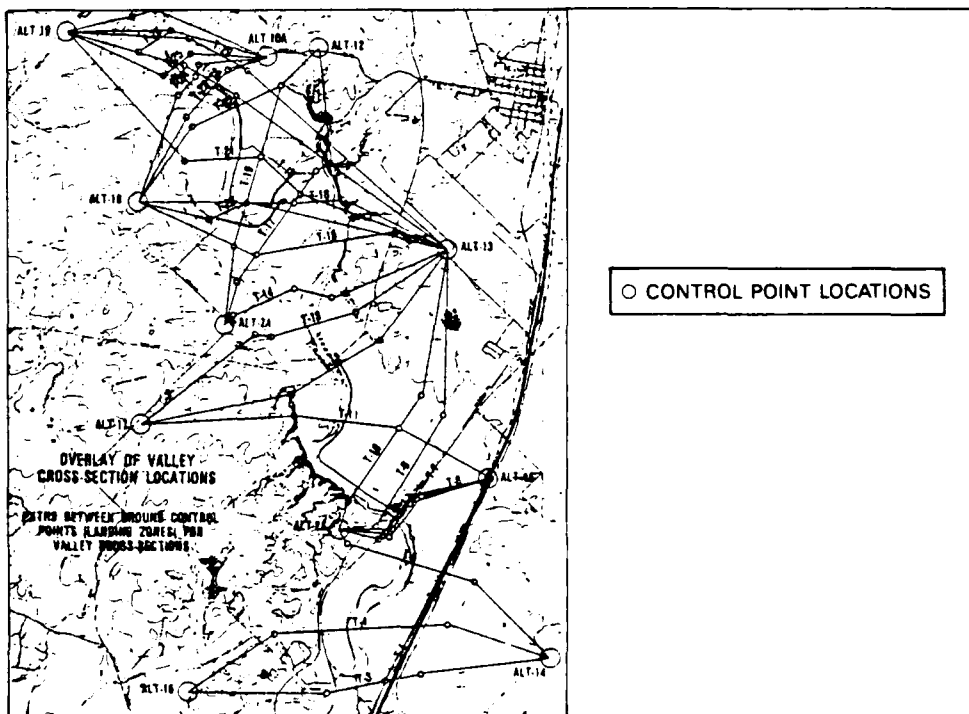

FIGURE 1

4

The objective that the test show the capability of LIDAR for performing in a production mode required that WES contract data collection to a commercial vendor with an existing LIDAR system. Commercial systems generally are of two types, those mounted on fixed-wing aircraft and those mounted on helicopters. For both types, aircraft position control is maintained by inertial guidance systems, and the guidance systems require repetitive updates to correct positional drift. On fixed-wing aircraft, updates are accomplished through microwave or laser links with known ground control points, such as in the prototype system developed by the USGS. Helicopter-mounted systems can be landed directly on known ground control points at regular intervals to accomplish positional update.

As a result of the WES contractor selection process, the firm of Nortec Surveys, Inc., of Calgary, Alberta, was awarded the LIDAR data collection contract. Nortec uses a helicopter-mounted LIDAR system. Figure 2 is a schematic of the Nortec system. WES personnel worked with Nortec representatives in establishing ground control landing zones suitable for the helicopter that were also near the terminus of cross sections selected for measurement.
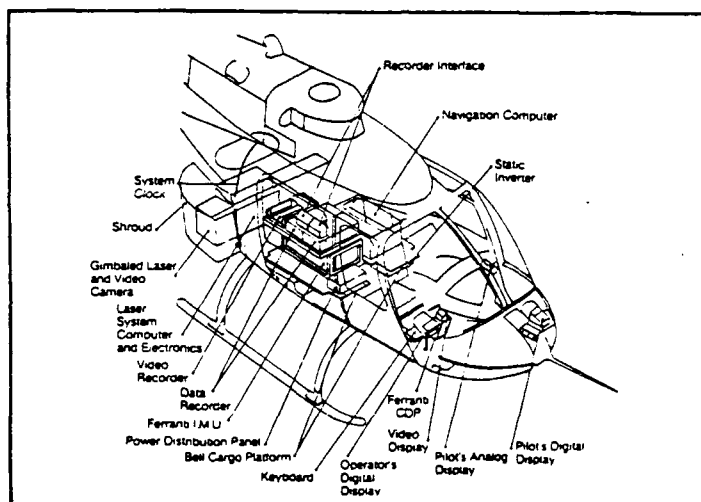

FIGURE 2

The airborne LIDAR surveying was conducted during the period of October 24 - November 4, 1985, for a total of 12 days. During this time, three days were lost due to inclement weather and one day due to instrumentation problems. The 29 valley cross sections, covering a distance of 322 km, were surveyed in three days. Helicopter altitudes varied from 25 to 40 meters, and the aircraft speeds ranged from 90 to 150 km/hr. Surveying was accomplished at a rate of 2.8 minutes/km to 4.2 minutes/km. The LIDAR pulse rate varied from 800 pulses/second to 1600 pulses/second (Stoll 1986). Upon completion of the surveying, Nortec provided listings of x,y, and z coordinates on magnetic tape to WES for the cross sections.

To provide data that could be compared to the LIDAR data, the Ft. Worth District and WES conducted ground surveys coinciding as closely as possible with 11 of the 29 LIDAR-surveyed cross sections.

V. ANALYSIS OF DATA

In evaluating the cross section data collected by the LIDAR system, considerable effort was devoted to developing an interactive graphics plotting capability to display and process the Nortec data provided on magnetic tape. The data provided by Nortec included three data points (a data point being a set of x, y, and z coordinates) for each laser pulse. The detector on the Nortec system records the longest time interval, the second longest time interval, and the shortest time interval for the transmission and reflection of the laser beam. When converting to elevation, the signal with the longest time interval is usually interpreted as having been reflected from the ground, and the signal with the shortest time interval is usually interpreted as having been reflected from the top of vegetation. The signal with the second longest time interval is usually interpreted as having been reflected from a surface slightly above the ground in vegetated terrain and by the ground surface in nonvegetated terrain. An example plot of a portion of a cross section is presented in Figure 3.
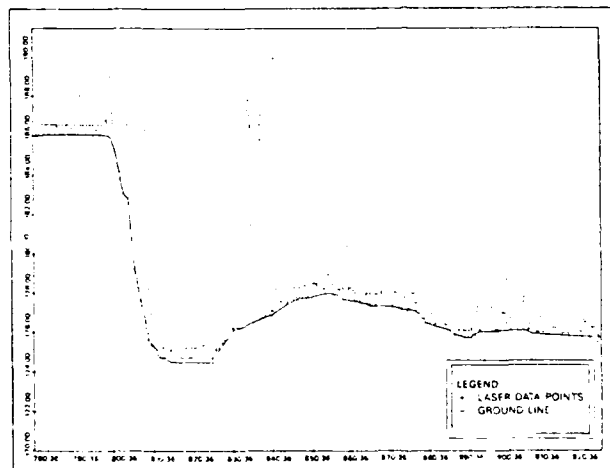

FIGURE 3

In interpreting the LIDAR data, several peculiarities of the data were observed. For example, in areas of fairly dense canopy cover, a portion of the laser beam may be reflected between the ground and the lower levels of the vegetative canopy one or more times before being reflected back to the light detector on the aircraft. As a result, a fairly long time interval is recorded for this portion of the beam, providing a false ground elevation data point.

LIDAR elevations recorded over hard surfaces, such as roadway pavements and shoulders in the test area, were found to differ from field-survey elevations by 1.455 to 0.398 meters (Stoll 1986, 2). These variations are the result of the different reflectivity of the hard surfaces and the soils and the leaf and grass cover typical of most of the study area. The highly reflective road pavement and shoulder surfaces result in the photo-diode detector reaching the threshold level (3dB) in less time than the off-road terrain surfaces. The 3dB threshold level is preset for typical terrain

conditions and could not be adjusted to accommodate shorter reflective energy response times.

Rural gravel roads and buildings were also found to be highly reflective surfaces. Natural features with highly reflective surfaces included the water and the light colored gravel bars of the Rio Blanco River channel.

For validation of the vertical and horizontal accuracy of the LIDAR data, field-survey data were collected for 11 of the 29 LIDAR cross sections. The field-survey data were collected at selected coordinates along cross sections T01, T02, T03, T04, T07, T13, T15, T16, T17, T20, and T23 (see Figure 1). The field-surveyed elevation at each coordinate location was compared with the LIDAR elevation at that coordinate location and the differences calculated. Table 1 provides a summary of the results.

TABLE 1: COMPARISON OF LIDAR AND FIELD-
SURVEYED GROUND ELEVATIONS

CROSS SECTION NUMBER	NUMBER OF POINTS COMPARED	MEAN DIFFERENCE*
T01	7	0.571
T02	69	0.527
T03	77	0.445
T04	94	0.388
T07	65	0.734
T13	24	0.591
T15	20	0.581
T16	35	0.456
T17	77	1.709
T20	41	0.444
T23	15	0.361
TOTAL	524	
AVERAGE		0.679

*elevations in meters

As shown by Table 1, the average difference between the field-survey elevations and the LIDAR elevations was 0.679 meters. This result is based on the inclusion of all of the data points for which both LIDAR and field-survey data were collected. Some sources of error can be isolated. For example, the LIDAR and field-survey data were collected at different times of year, and cropland was plowed after the LIDAR data collection and before the field survey. Another source of error is horizontal position control. The elevations of points that fall on steep slopes, such as river banks and bluffs, can change significantly due to slight errors in horizontal positioning. Horizontal coordinate position values for the LIDAR system are valid to within approximately one meter. Within a one-meter radius of a point on a near vertical slope, considerable elevation differences can occur. A final potential source of error are elevations collected for the

water surface of the Rio Blanco River. Again, the data sets were collected at different times of year, and it is unlikely that the water-surface elevations were identical during each data collection period.

If data points subject to the types of error discussed are not considered, the difference between the LIDAR elevations and field-surveyed elevations is reduced significantly. For example, if only those points located on relatively flat slopes with ground cover such as grass and trees are considered for cross section T03, the mean difference is reduced from 0.445 meters to 0.335 meters, a reduction of 25 percent. More dramatically, the elimination of a single data point from cross section T16 reduces the average difference between the LIDAR and field survey elevations from 0.456 meters to 0.270 meters, a reduction of 41 percent. At the data point removed from cross section T16, the difference between the LIDAR and the ground survey elevations was 1.871 meters. That point is located on a steep channel bank, where within the one-meter horizontal control radius of the LIDAR horizontal accuracy coordinate, significant changes in elevation occur.

In summary, comparisons of the LIDAR and field-survey results demonstrate that the average difference between the ground elevations determined for the same set of data points by both LIDAR and field survey can be held to 0.679 meters. And, as previously demonstrated, the average difference will be even less when data points at which the comparison of LIDAR and field survey elevations is not valid are eliminated from the data set. Accuracies demonstrated when such points are *removed from* the data set are within the accuracies for LIDAR terrain profiling demonstrated by the work of Krabill and approach the accuracies achieved by the prototype USGS APTS.

VI. RIO BLANCO HYDRAULIC MODEL

FISs performed by FIA determine through hydrologic and hydraulic analyses the elevations that would be attained by the 100-year flood. The 100-year flood is the flood that would occur, on the average, once every hundred years, or the flood with a one-percent probability of being equaled or exceeded in any given year. The magnitude of the 100-year flood discharge is established through various hydrologic techniques. In performing the hydrologic analysis of the Rio Blanco River, the Ft. Worth District COE arrived at an estimate of the 100-year flood discharge of approximately 4,420 cubic meters per second in the study reach.

The water-surface elevations that would be attained by the 100-year flood flowing through a river valley are calculated by performing hydraulic calculations in an iterative procedure generally know as the step-backwater method and perhaps best described by Chow (1959). The step-backwater method allows, for known flood discharges, friction effects, and floodplain cross section geometry, the calculation of water-surface elevations. Normally these tedious calculations are performed by a computer model, most commonly the HEC-2 model developed by the COE Hydrologic Engineering Center (1981).

In conducting the Hays County, Texas, FIS for FIA, the Ft. Worth District developed a HEC-2 hydraulic model of the Ric Blanco River. The elevation data required to describe the geometry of floodplain valley cross sections were obtained with aerial photogrammetric methods, as is standard for most FIS analyses. Bridge geometries and cross sections were obtained from field surveys. Hydraulic friction factors (Manning's "n") were determined through field inspections by Ft. Worth District personnel. The model output provides 100-year flood water-surface elevations at each cross section location. These water-surface elevations are referred to as base flood elevations (BFEs) and serve as the basis for floodplain regulation under the NFIP.

In order to evaluate the differences in determining flood elevations using LIDAR data instead of field-survey or photogrammetric data, the HEC-2 model was set-up a second time, using the LIDAR data as the source of elevation data for valley cross sections, and holding all other elements of the HEC-2 model constant. To perform this task a hydraulic engineer reviewed each LIDAR cross section and selected the points required for accurate hydraulic modeling within the HEC-2 model. Although each LIDAR cross section contains many hundreds of points, the HEC-2 model is limited to a maximum of one hundred points per cross section. The hydraulic engineer was therefore required to do substantial "screening" of the LIDAR data set to reduce the number of points describing the cross section geometry to a number within the constraints of the HEC-2 model.

The cross sections, as edited by the hydraulic engineer, were input to the HEC-2 model. The resultant water-surface profiles developed using the HEC-2 model and the LIDAR and photogrammetric cross-section data are shown in Figure 4. The results are also tabulated in Table 2.

A comparison of Tables 1 and 2 shows that, except at cross sections T16 and T20, the water-surface elevation differences are less than those between the LIDAR ground elevation data and the field-survey ground elevation data. That result is due to the selection of points by the hydraulic engineer. In creating a HEC-2 model, hydraulic engineers will select ground elevation points at the beginning and end of each cross section and at major breaks in ground slopes, but not generally along a uniform slope. The elevations of features such as houses are not normally described, and road surfaces, if indicated in the model at all, may be represented by a line between the two points delimiting the shoulder edges. Thus, in selecting LIDAR data points for use in the hydraulic model, the hydraulic engineer will eliminate many of the points where differences between the LIDAR and field-survey elevation data are greatest. As a result, the error introduced into the model will be reduced.

Furthermore, hydraulic calculations are much less sensitive to errors in cross sections that define steep-sided valley geometry than they are to errors in cross sections that define low-angle valley slope geometry. The reason for this difference is that total valley cross sectional area changes only slightly when inaccuracies in the definition of steep valley slopes are introduced. The inherent characteristics of airborne laser topographic surveying systems are peculiarly suited to the analytical

9

methods of hydraulic analysis in such a way that the effects of measurement inaccuracies are minimally manifested. This is because slight positioning inaccuracies on very steep slopes can yield large errors in ground elevations, but have insignificant effects on the results of water-surface analyses. Conversely, slight positioning inaccuracies for flat to gently sloping areas do not introduce significant errors in ground elevations that would greatly affect the total cross sectional area or the computed water-surface elevations. In summary, the omission of selected laser points on steep valley side slopes, where positional errors in the survey results yield gross errors in ground elevations, has very little effect on the computed water-surface elevations.

Figure 4 and Table 2 show that for cross sections T02 to T15, T21, and T23 to T25, the differences between the LIDAR-based and field-survey-based water-surface elevations are less than 0.3 meter. At the remaining cross sections, the difference increases to a maximum of 1.13 meters. The reason for this divergence is unclear, but it most likely can be attributed to a systematic error resulting from failure to update the inertial guidance system frequently enough for the flights in which terrain data were collected for cross sections T16 - T27. Due to the sequential nature of step-backwater calculations, poor vertical control at one cross section can affect subsequent water-surface elevation calculations. One indication of this is shown by Figures 5 and 6.

Figure 5 is a plot of the LIDAR cross section T14 developed by the hydraulic engineer overlaid on the conventional cross section from the Ft. Worth District HEC-2 model. It is clear that data points on these cross sections have nearly identical elevations. However, when a similar plot is prepared for cross section T18 (Figure 6), the cross section at which the maximum difference between water-surface elevations occurred, although the geometries of the cross sections are nearly identical, a vertical displacement of the ground profile is evident. For example, at the left channel overbank location, the conventional model ground elevation is 198.88 meters, while the LIDAR model ground elevation is 197.30 meters, a difference of 1.58 meters. Similarly, the left channel overbank ground elevation is 196.02 meters in the conventional model and 194.31 meters in the LIDAR model, a difference of 1.70 meters. Such a displacement cannot be explained by the error inherent in the LIDAR ranging system and is therefore most likely the result of a systematic problem with position control.

VII. EVALUATION OF LIDAR DATA FOR FIS APPLICATIONS

The accuracy of BFEs published by FIA as part of FISs prepared for NFIP communities is dependent on many factors. Fundamentally, the accuracy of all BFEs is affected to some degree by the accuracy of the hydrologic analysis used to derive the 100-year flood discharge used in the hydraulic model. The accuracy of the BFEs published by FIA as part of its FISs depends on the accuracy of both the hydrologic and hydraulic models used in those FISs. The purpose of the LIDAR demonstration project was to test the use of a LIDAR system to collect the ground elevation data on which FIS hydraulic models are based. Therefore, the evaluation of the level of

accuracy that could be attained with LIDAR-collected data focused on the performance of the hydraulic model in which those data are used and assumed that the results of the hydrologic analyses were correct.

TABLE 2: DIFFERENCE BETWEEN WATER-SURFACE ELEVATIONS* (WSELs) COMPUTED WITH LIDAR DATA AND WSELs COMPUTED WITH FIELD-SURVEY DATA

CROSS SECTION	LIDAR-BASED WSEL*	FIELD-SURVEY-BASED WSEL*	DIFFERENCE
T02	186.36	186.36	0.00
T03	186.41	186.49	0.08
T04	187.18	187.46	0.28
T05	189.42	189.36	-0.06
T07	190.84	190.67	-0.17
T09	192.17	192.13	-0.04
T10	192.54	192.60	-0.06
T11	194.83	194.94	0.11
T12	195.85	195.55	-0.30
T13	196.18	195.89	-0.30
T14	196.79	197.09	0.30
T15	198.02	198.14	0.12
T16	198.78	199.38	0.60
T17	200.23	200.66	0.43
T18	200.70	201.83	1.13
T19	202.63	203.63	1.00
T20	202.99	203.88	0.89
T21	204.83	204.89	-0.06
T22	205.68	206.09	-0.41
T23	206.56	206.79	0.23
T24	207.13	207.10	-0.03
T25	208.36	207.56	-0.08
T26	209.06	208.53	-0.53
T27	210.40	209.81	-0.59

*elevations in meters

FIGURE 4

CROSS SECTION T-14
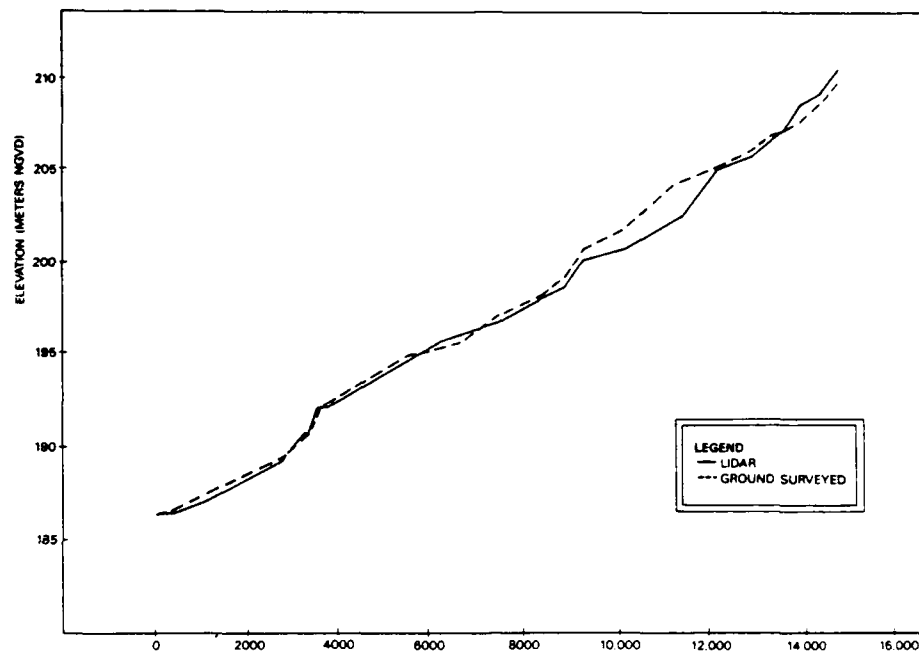
LEGEND
— LIDAR
--- GROUND SURVEYED

STATION (METERS)

FIGURE 5

12
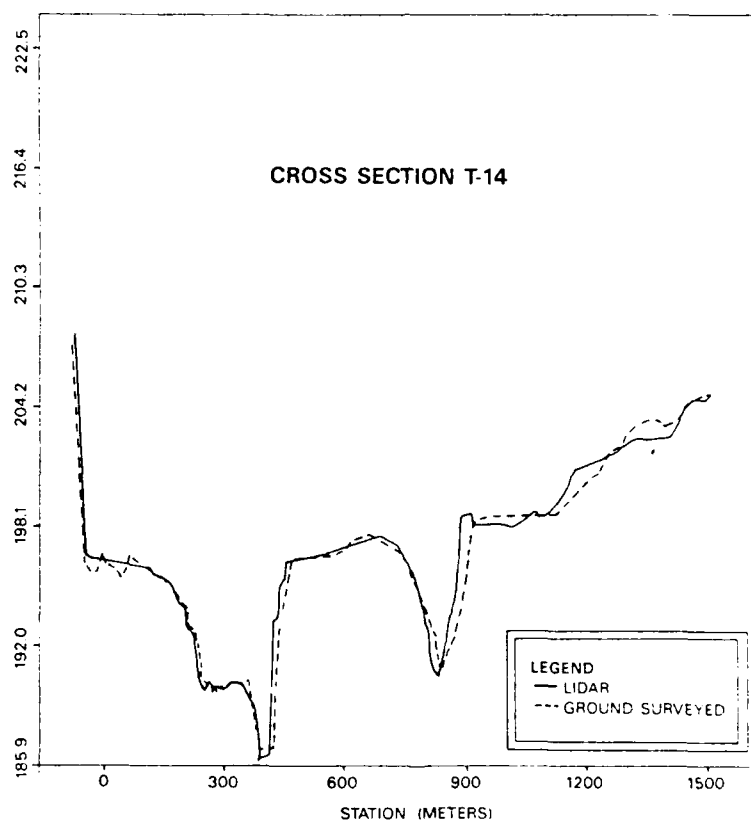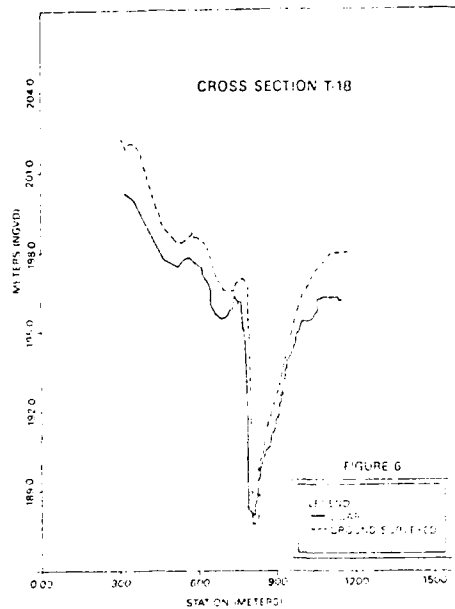
FIGURE 6

The sensitivity of the HEC-2 model to topographic data inputs has been studied by the COE (1986). As a result of its study, the COE has concluded that the accuracy of water-surface profiles resulting from HEC-2 modeling based on spot elevations derived from aerial photogrammetry varies with the contour interval of the photogrammetric map and the reliability of the Manning's "n" values. When values of Manning's "n" input to the HEC-2 model are of low reliability, the errors introduced into the water-surface profile calculations are several times those that result from errors in cross sectional data.

The COE study also shows that only small errors in computed water-surface profiles are introduced by the use of aerial spot elevation surveys. This outcome is attributed by the COE to the accuracy of photogrammetric methods and the randomness of measurement errors at individual coordinate points. Randomness of measurement errors results in hydraulically compensating errors, i.e., errors that offset one another and therefore do not significantly affect the computed water-surface elevations.

FIA guidelines for contractors performing FISs specifically provide for the use of photogrammetric techniques to develop cross sections for hydraulic models (FIA 1985). The specifications set forth in those guidelines require that 1.22-meter contour interval mapping be developed and that 90 percent of the spot elevations have an accuracy of plus or minus one-fourth the contour interval, about 0.3 meters.

The LIDAR data set developed in the demonstration project, when edited to remove data points for which comparison with ground survey data are invalid, had an average error that approached 0.3 meter. Furthermore, the water-surface elevations calculated with the LIDAR data at the first ten cross sections in the hydraulic model agreed closely with the elevations produced with photogrammetric data. Based on the results of the comparison of LIDAR ground elevation data with field-survey ground elevation data, and

13

the comparison of the results of the LIDAR-based and field-survey-based hydraulic models, there are strong indications that commercially available LIDAR surveying can produce topographic data of the quality required by FIA for FISs.

Before such a conclusion can be drawn from the Rio Blanco River data set, further editing of cross section data to remove data points invalid for comparison with the field-survey data will be required. Based on the edited data, 90-percent accuracy levels will be calculated to determine whether the data set will meet the 0.30-meter accuracy requirement for aerial-survey data used in FISs. In addition, reviews of the flight logs for the LIDAR data collection are required to identify the source of error that resulted in the divergence of the LIDAR HEC-2 profile from the conventional HEC-2 profile above cross section T16.

Aside from strictly considering the accuracy of the LIDAR data, the applicability of these data to the collection of cross section data for FIS hydraulic models is affected by other factors. Aerial survey flight times vary with cloud cover, sun angles, and vegetation cover. LIDAR systems are not affected by cloud cover, or by most ground haze, and the sun angle is of no importance. The Rio Blanco River test data were collected when the vegetation was fully foliated, and the LIDAR data penetrated to the ground surface consistently. Not having to schedule data collection times around vegetation foliation cycles adds flexibility to when floodplain analyses can be performed.

Other major advantages of the LIDAR system are the extremely rapid rate at which ground elevation data are collected and the density of the data set. As noted previously, LIDAR data were collected at rates of up to one kilometer every 4.2 minutes. Because the laser pulse rate is 1600 pulses per second the LIDAR system has the potential to record a ground elevation data point every few centimeters along the cross section.

A final advantage of the LIDAR data is that the data are collected in digital form. In developing the LIDAR hydraulic model for the demonstration project, the hydraulic engineer simply applied automated graphics and display software developed by WES to select desired HEC-2 input points from the LIDAR data set. The data file created was directly input to the hydraulic model. This procedure eliminates the need for the creation of digitized cross sections by photogrammetrists or the hand entry of data points into the hydraulic model.

The digital LIDAR data can also serve as the basis for creating digital elevation models (DEMs) to perform floodplain mapping. The capture of topographic data from hard-copy map sources is an expensive and tedious task. An example of the results of such an effort is the DEM for the Rio Blanco River study area shown in Figure 7. Direct capture of digital terrain elevation data in the field through a system such as LIDAR would allow for the creation of DEMs without the need to incur the expenses associated with digitizing hardcopy maps. Such DEMs could facilitate the FIS process by providing the basis for automating the mapping of floodplain boundaries using water-surface profiles and topographic data, as illustrated by Figure 8.

14

There are clear practical advantages to using LIDAR systems instead of aerial photography to collect data for FISs. These include greater flexibility in flying schedules, penetration through vegetation to the ground surface, and rapid, digital data collection. However, further analysis of the accuracy of the Rio Blanco River data set is required before commercial LIDAR systems can be conclusively deemed appropriate for use in FISs. At present, LIDAR systems should be used conservatively for the collection of topographic data for FISs, and ground elevation data should be collected independently to provide a means for verifying the performance of the LIDAR system.

VIII.   INTEGRATED EMERGENCY MANAGEMENT INFORMATION SYSTEM (IEMIS) FLOODPLAIN MAPPING

IEMIS (FEMA 1987) has been developed in response to the needs of emergency planners. A cornerstone of IEMIS is its spatial data analysis capabilities, including geographic information system (GIS) functions (Jaske 1985). Aside from mapping, IEMIS provides emergency planning models and data base utilities. To support the IEMIS objective of providing state and local governments with an automated system to aid in information sharing, joint planning, and emergency response simulation, and to provide a potential means of operational coordination, computer networking capabilities are incorporated within IEMIS. Computer networking capabilites can provide the mechanism by which FIA can maintain, revise, analyze, and distribute flood hazard maps.

To date, FIA has produced over 74,000 flood hazard maps depicting flood hazards in over 18,000 communities nationwide (Mrazik 1986). Multiple copies of each map are stored by FIA to meet requests for those maps from government officials, insurance agents and bankers, engineering firms, and private citizens. The number of flood hazard maps distributed by FIA each year is typically between six and seven million.

In addition to map distribution, map panels must be periodically updated and new flood studies are being continually performed that require incorporation into FIA's flood hazard mapping data set. The problems associated with the need to update, revise, store, and distribute large numbers of hardcopy maps have led FIA to evaluate various means by which flood hazard mapping can be automated (Cotter 1987). IEMIS's computer networking capabilities offer a means to create a system for electronic map distribution, as well as the means for automated map update.

However, before IEMIS's potential to fulfill these needs can be realized, technology that results in the creation of digital map data must be introduced into the flood hazard assessment process. The lack of digital topographic data is a primary constraint in the automated analysis of floodplains.
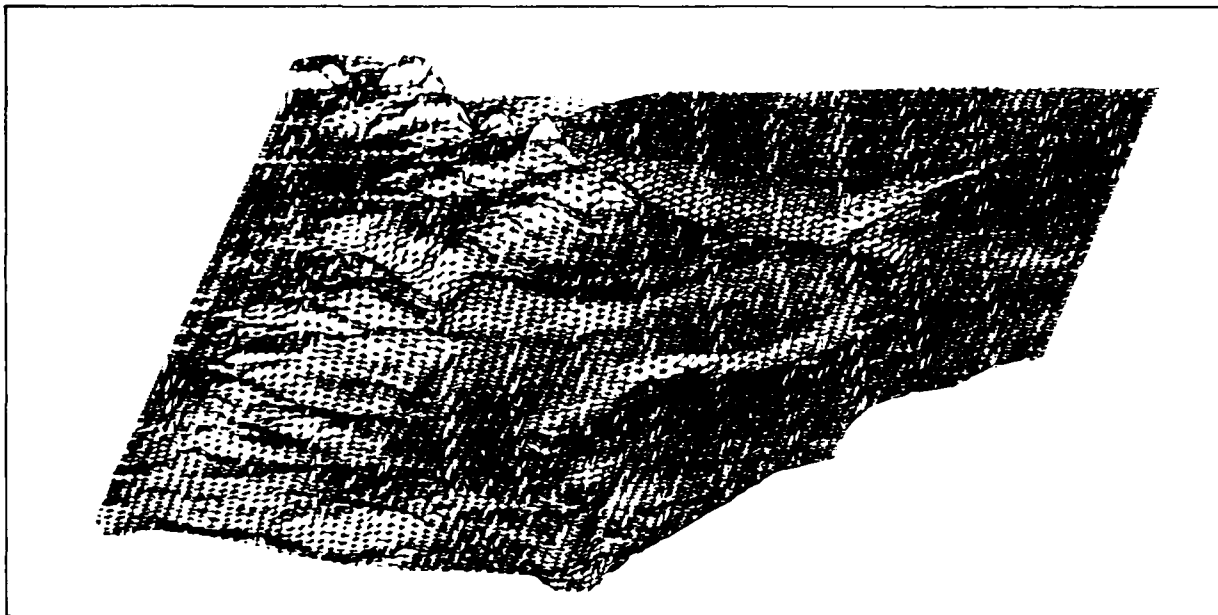
15

FIGURE 7

LEGEND
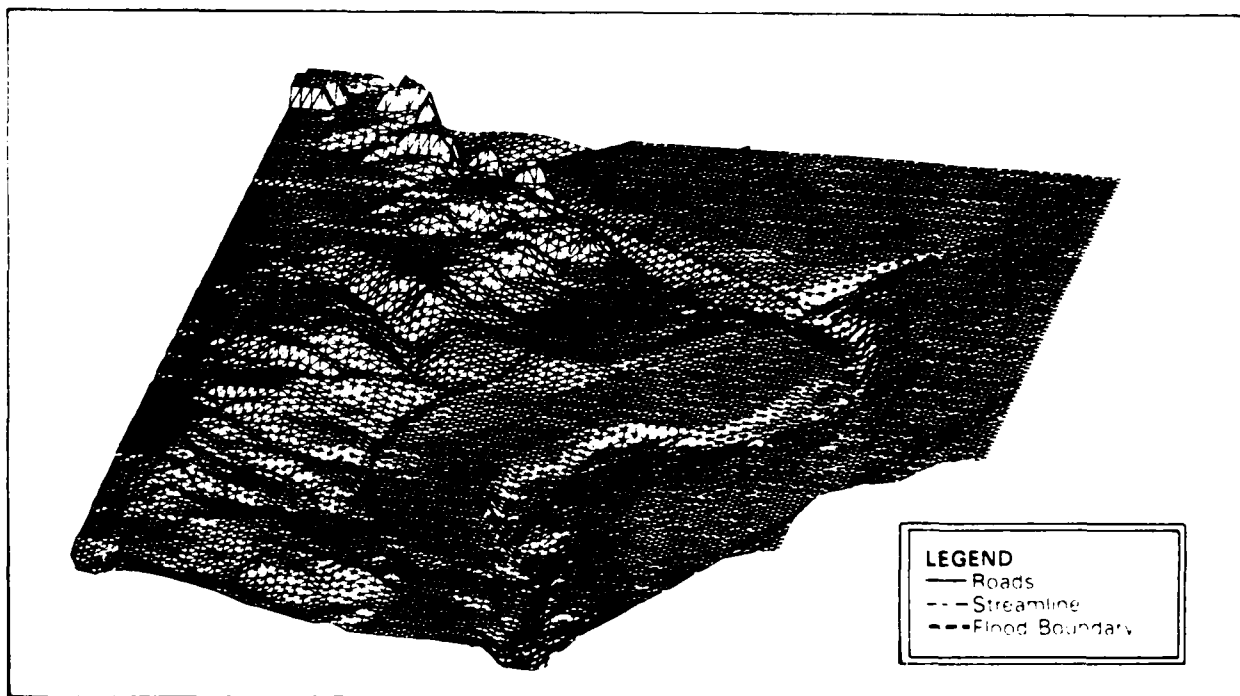—— Roads
– – –Streamline
– – –Flood Boundary

FIGURE 8

16

The Rio Blanco River LIDAR demonstration project shows that digital topographic data required by FISs can be collected in the field. The LIDAR cross section data were edited interactively by a hydraulic engineer, and the resulting cross sections read directly into the HEC-2 model for the calculation of water-surface profiles. Having created a water-surface profile, hydraulic engineers manually plot the water-surface elevations onto contour maps to show the extent of floodplains. The marked up maps are then sent to cartographers who produce final flood hazard maps based on the hydraulic engineer's analysis.

As a final step in the Rio Blanco River Demonstration Project, and as a means of demonstrating the feasibility of automating the production of flood hazard maps, WES computer-mapped the 100-year floodplain. To accomplish this, WES prepared a DEM, similar to the one shown in Figure 6, based on the 1:24000 scale USGS quadrangle for the area. The LIDAR-based water-surface elevations were then input to a flood simulator developed at WES, the Flood Analysis Simulation Technology (FAST) system. In addition to water-surface elevations and digital topographic data, FAST requires locations of the modeled cross section, river mile designations for each cross section, digital land use data, and river reach boundaries. Information that can be produced by the FAST system includes stage-area tables for each land use class, tables of depth versus area flooded, and floodplain maps for river stages and associated 1-foot water depth classes. For the demonstration project, maps of the 100-year floodplain were produced for both sets of water-surface elevations data given in Table 2. The results are illustrated in Figure 9. Figure 9 shows that the floodplains based on both the LIDAR and photogrammetric data are almost identical; the black areas depict the differences between the floodplains based on the LIDAR and photogrammetric data. The differences in the total flooded area based on the two data sets are summarized as follows:

DATA SET	FLOODED AREA IN HECTARES
Photogrammetric Data	868.5
LIDAR Data	836.5
Difference	32.0

The difference in flooded area represents 3.7 percent of the total flooded area, i.e., the 2 floodplains are 96.3 percent in agreement for the total area flooded.

The digital data set produced by FAST can be used to create an automated floodplain map such as the map shown in Figure 10.

The digital data set can also be readily transferred to the IEMIS environment. IEMIS has the capability to read data in standard ASCII format, the USGS Digital Line Graph format, as well as other digital data formats. Using these data translation tools, information such as digital flood hazard maps created in other computer environments can be loaded into IEMIS. Once within the IEMIS environment, these data can be combined with other data sets, edited, or otherwise enhanced, and serve as the basis for analytical modeling of emergency situations. In addition, through the

17

IEMIS computer network, the results of flood hazard analyses can be distributed, revised, and maintained.
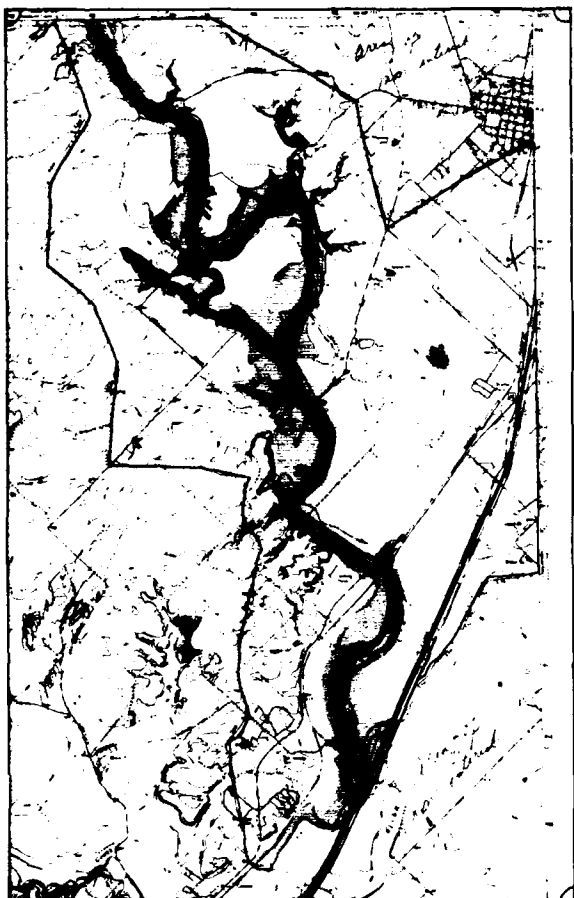

FIGURE 9

LEGEND
- - - Contour Interval
— Roads
- - - - Streamline
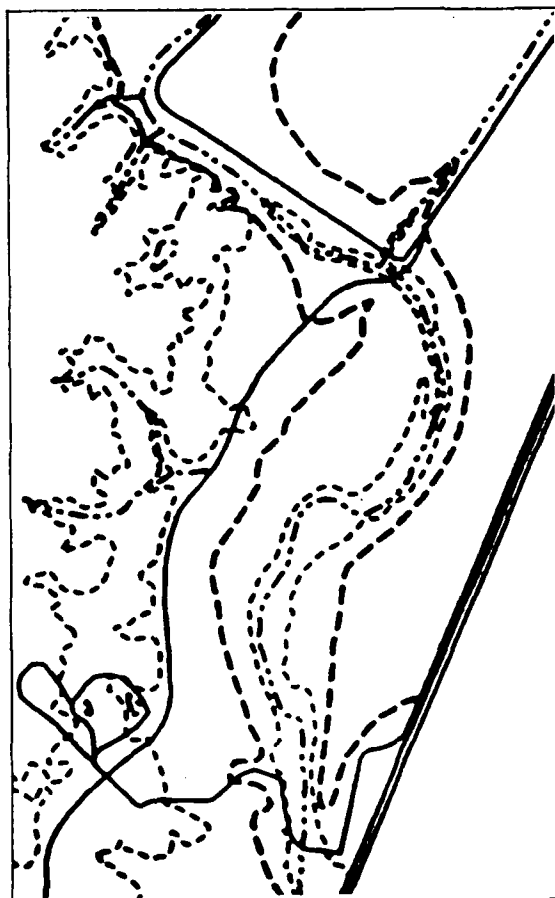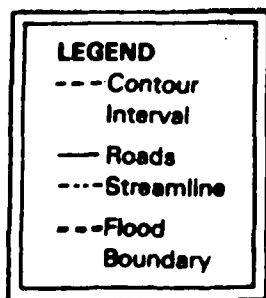- - - Flood Boundary

FIGURE 10

IX. SUMMARY

The LIDAR demonstration project has shown that ground elevation data required by FIA for FISs can be collected digitally, and rapidly, through the application of laser ranging technology. LIDAR technology offers some clear advantages in flexibility, speed, and data quantity over conventional surveying. Laser ranging technology is mature and precise; however, the ability to maintain aircraft position control at all times within accuracy limits that allow LIDAR data to be applied to FISs remains a challenge. The analysis of the test data indicates that, with due care and planning, this objective can be achieved.

IEMIS, with GIS, modeling, and networking capabilites, can be used to automate the revision, update, and analysis of flood hazard maps produced by FIA. The major constraint to the development of digital floodplain analyses is the lack of digital topographic data. Through application of FAST software, WES has demonstrated that digital LIDAR can make the automation of flood hazard analysis and mapping, and the exploitation of IEMIS for NFIP applications, feasible.

X. REFERENCES

(1) Brown, R.B., <u>Inertial Instrument System for Aerial Surveying</u>, U.S. Geological Survey Professional Paper 1390, U.S. Government Printing Office, Washington, D.C., 1987.

(2) Chow, V.T., <u>Open Channel Hydraulics</u>, McGraw-Hill, New York, 1959.

(3) Cotter, D.M.; Campbell, R.K., <u>Concept for a Digital Flood Hazard Data Base</u>, Vol. II of Proceedings Urban and Regional Information Systems Association, vols., pp. 156 - 170, Ft. Lauderdale, Florida, August 1987.

(4) Federal Emergency Management Agency, <u>Flood Insurance Study Guidelines and Specifications for Study Contractors</u>, FEMA 37, Federal Insurance Administration, September 1985.

(5) Federal Emergency Management Agency, <u>Integrated Emergency Management Information System Users Guide</u>, FEMA Manual SM 230, Washington, D.C., 1987.

(6) Hoge, R.E.; Swift, R.N.; Frederick, E.B., <u>Water Depth Measurement Using an Airborne Pulsed Neon Laser System</u>, Applied Optics 19(6):871-883, 1980.

(7) Jaske, R.T., <u>FEMA's Integrated Emergency Management Information System</u>, American Meteorological Association Proceedings, Los Angeles, California, January 1985.

(8) Krabill, W.B.; Link, L.E.; Butler, M.L., <u>Airborne Laser Topographic Mapping Results</u>, Photogrammetric Engineering and Remote Sensing, 50 (6): 685-694, June 1984.

(9) Mrazik, B.R., <u>Status of Floodplain Hazard Evaluation Under the National Flood Insurance Program</u>, Proceedings American Institute of Hydrology, Washington, D.C., September 1986.

(10) Stoll, Jack K., <u>Status Update of Airborne Laser Topographic Survey Demonstration</u>, Transportation Research Board, Committee A 2A01, Member Report, Workshop - Santa Fe, New Mexico, July 21 - July 25, 1986.

(11) Jet Propulsion Laboratory, <u>FIRMS, Flood Insurance Rate Mapping System</u>, Technical Section, JPL, California Institute of Technology, Pasadena, California, December 15, 1976.

(12) U.S. Army Corps of Engineers, <u>Accuracy of Computed Water Surface Profiles</u>, Hydrologic Engineering Center, Davis, California, December 1986.

(13) U.S. Army Corps Of Engineers, <u>HEC-2, Water Surface Profile, Users Manual</u>, Hydrologic Engineering Center, Davis, California, January 1981.

END
DATE
FILMED
DTIC
JULY 88